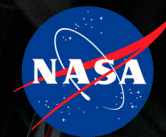


National Aeronautics and  
Space Administration



# MARSHALL

## SPACE FLIGHT CENTER

Marshall Star  
2021 Year in Review

Jan. 5, 2022



# Director's Corner: The Year of Artemis

The launch of the Imaging X-ray Polarimetry Explorer last month was the perfect way to ring in the new year and an example of overcoming adversity to achieve the extraordinary. IXPE will build upon Marshall's storied history in X-ray astrophysics, taking a bold and unique step forward by exploring the nature of stars, galaxies, and other celestial bodies in a new way.

Those same capabilities were critical to the development of NASA's next-generation space observatory – the James Webb Space Telescope. For more than two decades, Marshall team members were involved in the technology development and testing of the mirrors. Webb will study every phase of cosmic history, serving thousands of astronomers worldwide and it could not have been made possible without the critical and sustained contributions of many of you.

We accomplished so many milestones with the Space Launch System in 2021 – a successful Green Run test series, stacking of the solid rocket boosters, loading the flight software and, now, the Artemis I rocket being fully stacked in the Vehicle Assembly Building at Kennedy Space Center. Looking back at those accomplishments and seeing how close we are to realizing a dream more than a decade in the making fills my heart with pride and hope for what is yet to come.

It was a busy way to end 2021 and I hope you could feel the momentum from all of NASA's incredible missions of exploration and discovery as we enter the new year. As we approach the first launch of the SLS on the Artemis I mission, it is only possible because of your hard work, expertise, and dedication. Whether you are working from home or on-site, you proved time and time again that no obstacle could stand in the way of accomplishing our goals.

We have one more major milestone to check off the list before we launch Artemis I – the wet dress rehearsal, when engineers will load cryogenic propellant in the core stage and Interim Cryogenic Propulsion Stage. I can't wait to watch the rocket come to life, launching a new era of human deep space exploration and solidifying 2022 as The Year of Artemis.

For the Artemis I mission and beyond, Marshall will continue to play a vital role in NASA's deep space architecture – from liftoff to landing. Our Human Landing System team is working with our commercial partners to develop the first human lunar lander in 50 years!

I look forward to watching their progress in the coming years to mature concepts and designs that will establish a long-term human presence at the Moon.

While we look to the future with Artemis, our center continues to support NASA's current human space flight efforts with the Commercial Crew Program. Marshall team members did an excellent job supporting the Crew-2 and Crew-3 missions. Even though they made it look easy, that team worked many challenging issues over the past year to help ensure mission success.

Our Payload Operations team, which celebrated 20 years of continuous science operations on the International Space Station last year, continues to amaze me with their support of the station, 24 hours a day, 365 days a year. The 4-Bed Carbon Dioxide Scrubber – designed at Marshall and recently installed on the station – is an example of how Marshall's innovative approach to improving research and life-support hardware serves as a test bed for the exploration systems and capabilities we will need for future missions.

This year will bring some big changes for our infrastructure, including officially moving Marshall's headquarters into Building 4221 and the demolition of Building 4201, which will open up the central greenway envisioned in our master plan. This is all part of our effort to improve and upgrade our infrastructure to support our workforce and our missions.

Marshall is strong because of you and the ways you contribute to your work each day. I can't promise there won't be more challenges in the year ahead, but I am confident in your ability to deliver on the mission!

**Jody**



**Marshall Director  
Jody Singer**

## Marshall Science Mission Among Four Selected for New NASA Pioneers Program

NASA chose four small-scale astrophysics missions – including one led at Marshall – for further concept development in a new program called Pioneers. Through small satellites and scientific balloons, these selections will enable new platforms for exploring cosmic phenomena such as galaxy evolution, exoplanets, high-energy neutrinos, and neutron star mergers. Among the selections was the StarBurst mission. Led by principal investigator Daniel Kocevski at Marshall, StarBurst is a SmallSat instrument payload intended to detect high-energy gamma rays from powerful cosmic events – such as the mergers of neutron stars, seen here in an illustration, or dense remnants of collapsed stars gone supernova.

## Chandra Adds Data, Raises New Questions About Extraordinary Magnetar

In 2020, astronomers added a fascinating new object to an exclusive family of exotic phenomena with the discovery of a powerful magnetar. Now, observations made using NASA's Chandra X-ray Observatory add credence to the theory that it's also a pulsar – a compact, spinning star which emits powerful pulses of electromagnetic radiation. Magnetars – highly dense neutron stars formed from the collapsed core of stars gone supernova – are unique among neutron stars for possessing the most powerful known magnetic fields in the universe. Marshall manages the Chandra program for NASA.

## Marshall Leaders Discuss Challenges, Tactics

Throughout 2021, Marshall managers shared their insights on leading during a pandemic, staying mission-focused, and honoring diversity and inclusion, in the monthly Take 5 profile series. The Star interviewed leaders from the Office of Human Resources, Safety and Mission Assurance Directorate, Human Exploration Development & Operations Office, Space Launch System program, Planetary Missions Program Office, Small Business Office, Payload and Mission Operations Division, Human Landing System program, Space Nuclear Propulsion, and NASA's Inter-Agency Implementation and Advanced Concepts Team.

# JANUARY



## Perseverance Rover Safely Lands on Mars

On the afternoon of Feb. 18, people around the world held their breath in anticipation of NASA's **Perseverance rover landing** – the largest and most complex of its kind sent to the Red Planet. For mission control teammates at NASA's Jet Propulsion Laboratory, who helped monitor that journey, the wait would be rewarded seven minutes after the rover's descent through the Martian atmosphere. At that moment, jubilation erupted. The rover got its wheels safely in the famed red dirt. Team members at Marshall played an important role in the mission, including planetary scientist Caleb Fassett, who championed Jezero Crater as the mission's landing site.



## Marshall Leads Launch Abort System Integration, Transition

Teams across Marshall are **preparing the agency's Launch Abort System** – a component positioned atop the Orion crew module to protect astronauts in launch – for upcoming Artemis missions. In the case of an emergency, three solid rocket motors work together to propel astronauts to safety. The abort motor pulls the crew module away from the rocket, the attitude control motor steers and orients the capsule, then the jettison motor ignites to separate the Launch Abort System from Orion prior to parachute deployment to ensure a safe crew landing.

## Love and Rockets

NASA's mission is a marriage of science and exploration, a blend of hard-headed practicality and old-fashioned soaring romance. A belief in building something greater than oneself and leaving the world a better place than it was before. No surprise then, that Marshall is home to so many **successful working couples** – whose personal lives are built on the same shared drive and passion that fires their imaginations and fuels their careers.

# FEBRUARY



## Payload Ops: Achievement in Orbit, Increased Role in Future

A marvel of teamwork, the International Space Station is home to round-the-clock science, with some 200 experiments underway at any given moment, overseen by astronauts and science teams on the ground. Marshall **oversees all payloads** from its Payload Operations Center, monitoring use of the 15 unique science hardware facilities developed, built, and managed there for the agency. Marshall's payload operations are **preparing for additional responsibilities** over the next 10-15 years as NASA plans for parallel human mission and payload operations in low-Earth orbit, deep space near the Moon, on the lunar surface, in transit to Mars, and ultimately on and around the Red Planet.

## SLS Rocket Boosters Stacked for Artemis I, Core Stage Passes Key Test

On March 2, Engineers and technicians with Exploration Ground Systems at Kennedy Space Center **completed stacking** of the twin solid rocket boosters for the Space Launch System rocket by lowering the final nose assembly on top of the fifth motor segment. The SLS solid rocket boosters are the largest ever built for spaceflight – each booster is more than 17 stories tall. On March 18, the SLS core stage – the largest rocket element NASA has ever built – fired its four RS-25 engines for 8 minutes and 19 seconds at Stennis Space Center. Engineers designed the eight-part Green Run test campaign to gradually bring the SLS core stage to life for the first time, **culminating with the hot fire**. The team used data from the tests to validate the core stage design for flight.

## Marshall Spinoffs Provide Benefits in Space, on Earth

Newly reported **spinoffs from Marshall** offer an unlikely pair of benefits for space and commercial applications. An insert made from space-age material helps reduce pungent shoe odors, and an advanced 3D printer enables printing of electronics on demand. They are just two examples of how NASA investments in the advancement of aeronautics and exploration of space are used in everyday life.

# MARCH



## First of two NASA SpaceX Commercial Crew Missions in 2021 Launches

NASA's SpaceX Crew-2 astronauts **launched from Kennedy Space Center** on April 23 and boarded the International Space Station on April 24 to begin the second commercial crew rotation mission aboard the microgravity laboratory. Team members at Marshall worked on certifying the first-time reuse of the Crew-1 booster for Crew-2. Marshall also worked on booster maintenance and refurbishment. The Crew-3 mission **launched** Nov. 11.



## SLS Core Stage for Artemis I Arrives at Kennedy

On April 29, crews **guided the final piece** of NASA's Space Launch System rocket that will send the agency's Artemis I mission to the Moon to the Vehicle Assembly Building at Kennedy Space Center. The agency's Pegasus barge ferried the 212-foot-tall core stage from Stennis Space Center, where it underwent a successful Green Run test series, to the Space Coast. After a 900-mile journey, teams aboard the barge safely piloted the specialized self-sustaining vessel to the spaceport's Launch Complex 39 turn basin wharf on April 27.

## NASA Picks SpaceX to Land Next Americans on Moon

NASA is getting ready to send astronauts to explore more of the Moon as part of the Artemis program, and the agency **selected SpaceX** to continue development of the first commercial human lander that will safely carry the next two American astronauts to the lunar surface. Those astronauts will transfer from the Orion spacecraft to the SpaceX human landing system for the final leg of their journey to the surface of the Moon. After approximately a week exploring the surface, they will board the lander for their short trip back to orbit where they will return to Orion before heading back to Earth.

# APRIL



### 3D-Printed Rocket Engine Hardware Passes Cold Spray, Hot Fire Tests

NASA is partnering with Aerojet Rocketdyne to advance **3D printing technologies** for liquid rocket engines in landers and in-orbit stages/spacecraft. The Robotic Deposition Technology Team, led from Marshall, is designing and manufacturing innovative and lightweight combustion chambers, nozzles, and injectors that will incorporate automated robotic deposition 3D-printing technologies: cold spray deposition, laser wire direct closeout, laser powder bed fusion, and laser powder directed energy deposition. The goal is to evolve these processes using weight-optimized materials to validate operability, performance, and reusability through hot fire testing. Here, a lightweight combustion chamber and nozzle undergo a hot fire test.

### NASA Rewards Ingenuity, Creativity Through Centennial Challenges

On May 20, NASA **awarded \$500,000** to seven winning teams in Phase 1 of the agency's Watts on the Moon Challenge. The technology design competition challenged U.S. innovators, from garage tinkerers to university researchers and startup entrepreneurs, to imagine a next-generation energy infrastructure on the Moon. The challenge is part of Centennial Challenges, based at Marshall. Over the course of 2021, winners were also were selected in four other competitions: The **CO2 Conversion Challenge**, **Break the Ice Lunar Challenge**, **Space Robotics Challenge**, and **Deep Space Food Challenge**.

### OSIRIS-REx Heads for Earth with Asteroid Sample

After nearly five years in space, NASA's Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer – OSIRIS-REx – spacecraft **began its way back to Earth** on May 10 with an abundance of rocks and dust from the near-Earth asteroid Bennu. The spacecraft is due to reach Earth on Sept. 24, 2023. OSIRIS-REx is the third mission in NASA's New Frontiers Program, managed by the Planetary Missions Program Office at Marshall for the agency's Science Mission Directorate.

# MAY





## Marshall Scientists Use Lightning to Help Predict Hurricane Intensity

Instead of chasing storms, a team of Marshall researchers uses new weather prediction methods to see storms ahead of time. By **studying lightning**, the scientists are working to develop new ways to help forecast the intensity of incoming hurricanes. Typically, an increase in lightning within the storm signals that the storm is likely to strengthen. But sometimes even weakening hurricanes have large lightning outbreaks, so forecasters must carefully analyze additional data to determine what a lightning outbreak really means for predicting a hurricane's intensity. A team of scientists led by Marshall researcher Patrick Duran published a study on the evolution of lightning flash density, flash size, and flash energy during Hurricane Dorian -- below, as seen from the International Space Station.

## NASA Announces Winners of Rover Challenge, Student Launch

For nine months, high school and college teams strived for success in NASA's 2021 Student Launch competition. Countless hours were poured into the design, simulation, construction, testing, and launch of rockets and payloads. On June 3, **teams were awarded** during a virtual ceremony. In an April virtual ceremony, NASA **announced the winners** of the Human Exploration Rover Challenge, a competition in which student teams spent eight months designing, building, and testing a human-powered rover on a course that simulates the terrain found on rocky bodies in the solar system. Marshall manages both competitions, which are part of NASA's Artemis Student Challenges.

## Marshall Reimagines, Plans for Post-Pandemic Productivity

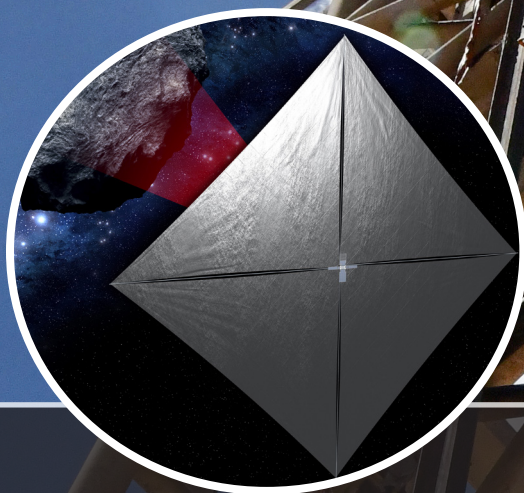
As the world continued to attempt to define "the new normal," Marshall **carved out its version** of what ordinary will look like once the COVID-19 pandemic has passed, joined with an agencywide Future of Work initiative. In one year, Marshall transitioned from a traditional on-site work environment to majority teleworking in response to the pandemic. Leadership then envisioned an environment where telework is more common and team members work where and how they can be most productive.

# JUNE



## NASA Launches X-ray Spectrometer Mission to Probe Mysteries of Solar Corona

On July 30, NASA researchers **successfully launched** a sophisticated X-ray solar imager on a brief but potentially illuminating suborbital flight via sounding rocket to gather new insight regarding how and why the Sun's corona grows so much hotter than the actual surface of Earth's parent star. The mission, named "MaGIXS" – short for Marshall Grazing Incidence X-ray Spectrometer – launched from White Sands Missile Range in New Mexico. Marshall heliophysicist Amy Winebarger is the mission's principal investigator.



## NASA Solar Sail Asteroid Mission Readies for Launch on Artemis

NASA's Near-Earth Asteroid Scout is tucked away safely inside the agency's powerful Space Launch System rocket at Kennedy Space Center. The **solar-sailing, shoebox-sized CubeSat** is one of several secondary payloads hitching a ride on Artemis I, the first integrated flight of SLS and NASA's Orion spacecraft. NEA Scout will be America's first interplanetary mission using solar sail propulsion. Marshall's Les Johnson is the mission's principal technology investigator.

## Pair of Artemis I Components Stacked

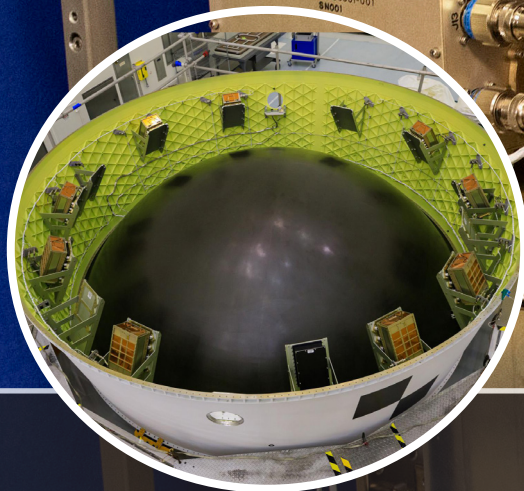
On July 5, teams with Exploration Ground Systems and contractor Jacobs at Kennedy Space Center **stacked the Interim Cryogenic Propulsion Stage**, or ICPS, atop the Space Launch System rocket for the Artemis I mission. The ICPS will fire its RL 10 engine to send the Orion spacecraft toward the Moon. Orion was stacked later in the month, and the launch abort system, with **its aerodynamic shape**, crowned the spacecraft.

# JULY



## Trio of Payloads with Marshall Ties Launch to Space Station

Three experiments **with ties to Marshall** – the 4-Bed Carbon Dioxide Scrubber (seen here), the Redwire Regolith Print study, and the ring-sheared drop investigation – **launched** to the International Space Station on Northrop Grumman's 16th commercial resupply services mission Aug. 10. The experiments added to a long list of studies conducted during more than 20 years of continuous human habitation of the orbiting lab, helping researchers explore farther into space and benefiting humans back on Earth.



## Artemis I Flight Software Installed, CubeSats Readied

On Aug. 6, engineers at Kennedy Space Center **loaded the flight software** that will help steer, fly, track, and guide the Space Launch System rocket during launch and ascent to space. Once installed, the Marshall engineers who developed the flight software supported final checkouts and completion of tests to certify the software for the mission. Additionally, technicians from Exploration Ground Systems and contractor Jacobs worked with CubeSat developers as the shoebox-sized secondary payloads underwent final processing and **were secured** inside the ring-shaped Orion Stage Adapter, seen above. All CubeSats will be deployed after SLS completes its primary mission of launching the Orion spacecraft on a trajectory toward the Moon.

## Marshall Proposals Selected to Help Advance Deep Space Human Exploration

NASA's Advanced Exploration Systems division announced that 10 proposals led by early-career employees at eight NASA centers were selected for two-year projects that will enable new capabilities for deep space human exploration. Teams submitted proposals to Project Polaris, a new initiative to help NASA's workforce meet the challenges of sending humans to the Moon and Mars. Two of the selections **came from Marshall**: The Bioremediation of Microgravity Biofilms and Water Processor Health proposal, led by J.P. Wilson, and the Data Planning and Control Tool proposal, led by Mason Hall.

# AUGUST





## NASA Selects Five U.S. Companies to Mature Artemis Lander Concepts

NASA **selected five U.S. companies** to help the agency enable a steady pace of crewed trips to the lunar surface under the agency's Artemis program. These companies will make advancements toward sustainable human landing system concepts, conduct risk-reduction activities, and provide feedback on NASA's requirements to cultivate industry capabilities for crewed lunar landing missions. The selected companies were Blue Origin, Dynetics (a Leidos company), Lockheed Martin, Northrop Grumman, and SpaceX.

## 60 Years of Pride, Dedication on Display at Michoud During Hurricane Ida

On Aug. 29, 2021 – 16 years to the day of Hurricane Katrina, one of the most devastating storms to make landfall along the Louisiana/Mississippi Gulf Coast – emergency crews at NASA's Michoud Assembly Facility found themselves in familiar territory. As Hurricane Ida threatened the facility, the team **demonstrated the same fierce commitment** to its mission as it has for 60 years; and once again protected vital equipment from serious damage.

## NASA Readies for Future Artemis Moon Missions with Rocket Engine Test Series

NASA **marked a significant milestone** Sept. 30 in its plans for future missions to the Moon and eventually Mars with completion of an RS-25 single-engine Retrofit-2 test series at Stennis Space Center. A full-duration hot fire of RS-25 developmental engine No. 0528 on the A-1 Test Stand concluded a seven-test series to support development and production of new engines for the agency's Space Launch System rocket on future missions.

# SEPTEMBER





## **NASA, ULA Launch Lucy Mission to 'Fossils' of Planet Formation**

NASA's Lucy mission, the agency's first to Jupiter's Trojan asteroids, **launched Oct. 16** on a United Launch Alliance Atlas V rocket at Cape Canaveral Space Force Station in Florida. Over the next 12 years, Lucy will fly by one main belt asteroid and seven Trojan asteroids, making it the agency's first single spacecraft mission to explore so many different asteroids. Lucy is the 13th mission in NASA's Discovery Program, which Marshall manages through its Planetary Missions Program Office.

## **NASA Completes Mega-Moon Rocket Stacking**

NASA **completed stacking** of the agency's mega-Moon rocket and spacecraft that will launch the next generation of deep space operations. Engineers and technicians successfully secured the Orion spacecraft atop the fully assembled Space Launch System rocket at Kennedy Space Center just before midnight Oct. 21. With stacking complete, a series of integrated tests sit between the rocket and targeted liftoff of the Artemis I uncrewed mission in spring 2022.

## **NASA Leaders Visit Huntsville, Laud Unity, Teamwork**

Jim Reuter, associate administrator for NASA's Space Technology Mission Directorate, presented the opening keynote address at the 14th annual **Wernher von Braun Memorial Symposium** on Oct. 12 at the University of Alabama in Huntsville. Jim Free and Kathy Lueders – associate administrators for the new Exploration Systems Development and Space Operations mission directorates, respectively – discussed the teamwork involved in making human space exploration possible. NASA Associate Administrator Robert Cabana closed the symposium with his keynote Oct. 14. He also **toured Marshall**, visiting the Systems Integration Lab, Additive Manufacturing, the Environmental Control and Life Support System Laboratory, and the Nuclear Thermal Propulsion Laboratory.

# OCTOBER



## NASA Administrator, Deputy Administrator Visit Marshall, Michoud

NASA Administrator Bill Nelson – seen here with Marshall Director Jody Singer – and Deputy Administrator Pam Melroy **visited Marshall** on Nov. 29-30 for tours and briefings on the center's role in the Artemis program and other capabilities that enrich many facets of the nation's space exploration endeavors. Nelson and Melroy **visited Michoud Assembly Facility** on Dec. 8. Workers at Michoud – NASA's rocket factory – are building components for the SLS rocket and Orion spacecraft that will return humans to the Moon.

## NASA, SpaceX Launch DART: First Test Mission to Defend Planet Earth

NASA's Double Asteroid Redirection Test (DART), the world's first full-scale mission to test technology for defending Earth against potential asteroid or comet hazards, **launched Nov. 24** on a SpaceX Falcon 9 rocket at Vandenberg Space Force Base in California. DART will impact a known asteroid that is not a threat to Earth. Its goal is to slightly change the asteroid's motion in a way that can be accurately measured using ground-based telescopes. DART is a project of Marshall's Planetary Missions Program Office.

## Marshall Celebrates Future of Human Exploration with Artemis on the Square

Visitors to Huntsville's courthouse square Nov. 6 enjoyed space exhibits, live music, and activities as part of **Artemis on the Square**. More than 150 attendees donned astronaut attire in an attempt to break the world record for most people dressed like an astronaut in one place. "While the whole nation is a part of our mission, here in Huntsville, we have a lot to proud of, with more than 60 years of space exploration in our DNA," Marshall Director Jody Singer told the crowd. "Artemis is NASA's next great space exploration mission, and this mission will be flown on the Space Launch System rocket, managed right here at Marshall with contributions from suppliers in 45 states across the country."

# NOVEMBER





### Three Science, Technology Demonstration Missions Fly

The thunder of liftoff echoed repeatedly in December. NASA launched its **Laser Communications Relay Demonstration mission** Dec. 7 to test delivery of infrared laser data up to 100 times faster than conventional radio frequency systems. Marshall manages LCRD as part of NASA's Technology Demonstration Missions program. The **Imaging X-ray Polarimetry Explorer** launched Dec. 9 (left) to measure polarized X-rays emitted by black holes, supernova remnants, and other distant objects. Marshall built IXPE's three telescopes, and Martin Weisskopf, chief of X-ray astronomy at Marshall, is the mission's principal investigator. And Dec. 25, NASA, the European Space Agency, and the Canadian Space Agency launched the **James Webb Space Telescope**, the scientific successor to NASA's Hubble and Spitzer telescopes, to study the early universe and distant exoplanets. Marshall **helped develop the telescope** and conducted exhaustive testing of its mirror segments (above).

### Readying for Artemis I in Engineering Support Center

As NASA prepares to launch its Artemis I mission, crews in Marshall's **Space Launch System Engineering Support Center** are running simulations to practice their role in exploring the Moon and beyond. The support center will monitor data and provide engineering expertise during Artemis launches, connected in real time with Kennedy Space Center launch teams and others supporting the mission all over the United States, helping resolve any issues that arise to keep the Artemis I countdown on track and ensure mission success.

### NASA Completes Assembly of Upper Part of Artemis II Core Stage

In December, NASA **completed assembly** of the upper part of the Space Launch System core stage that will send the Artemis II crew to the Moon. Boeing engineers completed stacking the three major parts of the stage – the forward skirt, the liquid oxygen tank, and the intertank – and lifted the finished portion of the rocket out of the assembly structure at Michoud Assembly Facility. The upper part of the stage is approximately 66 feet tall. Once assembled, the completed rocket will stand 212 feet tall.

# DECEMBER